Economic Impact Analysis of Disposal Options for Produced Waters from Coalbed Methane Operations in EPA Region 8

U.S. EPA

Public Meeting

Billings, MT

September 25, 2001

Agenda

- Welcome and Introduction
- Effluent Guidelines Program
- Overview of CBM Operations in Region 8
- Potential Impacts from CBM Produced Water
- Description of EPA's Data Collection
- Description of Potential Disposal Options
- Description of Engineering Costing Methodology
- Description of Economic Impact Methodology
- List of Data Needs
- Schedule for Completion of Analysis

Purpose of Analysis

- Support determination of effluent limitations representing Best Available Technology Economically Achievable (BAT) for CBM produced waters
- Support EPA permitting in American Indian Tribal Country
- Inform the States and EPA in the implementation of their NPDES permit programs

Clean Water Act

- Technology-based limitations
  - Set minimum standard of performance for discharger based on control technology or process changes
  - Does not consider the quality of receiving waters
- Water-quality based limitations
  - Identify intended uses of water body
  - Set biological and chemical conditions necessary to sustain those uses

Best Available Control Technology Economically Achievable (BAT)

- Best performance economically achievable of operations with common characteristics
- BAT is focused on treatment of toxic and other nonconventional pollutants
- BAT represents application of the best controls, including in-plant process changes and technology transfer from other industries, which are affordable by the industry as a whole or large segments of the industry
- Affordable is based on product line and/or plant closures and job losses

Effluent Limitation Guidelines and Standards (ELGs)

- National industrial wastewater regulations for both direct and indirect dischargers
- Industry specific
- Numerical, technology performance-based limitations
- Economically achievable

NPDES Permits

- Tools used to implement and enforce effluent limitation guidelines
- Written by EPA regions and delegated state agencies for direct dischargers
- Permit writers use Best Professional Judgment (BPJ) when effluent guidelines are not available for an industrial category or subcategory
  - Coalbed methane gas production subcategory not specifically addressed under Oil and Gas ELGs
  - BPJ must consider same factors as national ELGs

BPJ Basis: Oil and Gas Point Source Category (40 CFR Part 435, Subpart E)

- No discharge unless the discharge of produced water occurs west of the 98th meridian and is used for agricultural purposes and/or wildlife propagation
  - Produced water shall be of good enough quality to be used for wildlife or livestock watering, or other agricultural uses
  - Produced water shall be put to such use during periods of discharge
  - Discharges shall not exceed a daily maximum limitation of 35 mg/l for Oil and Grease

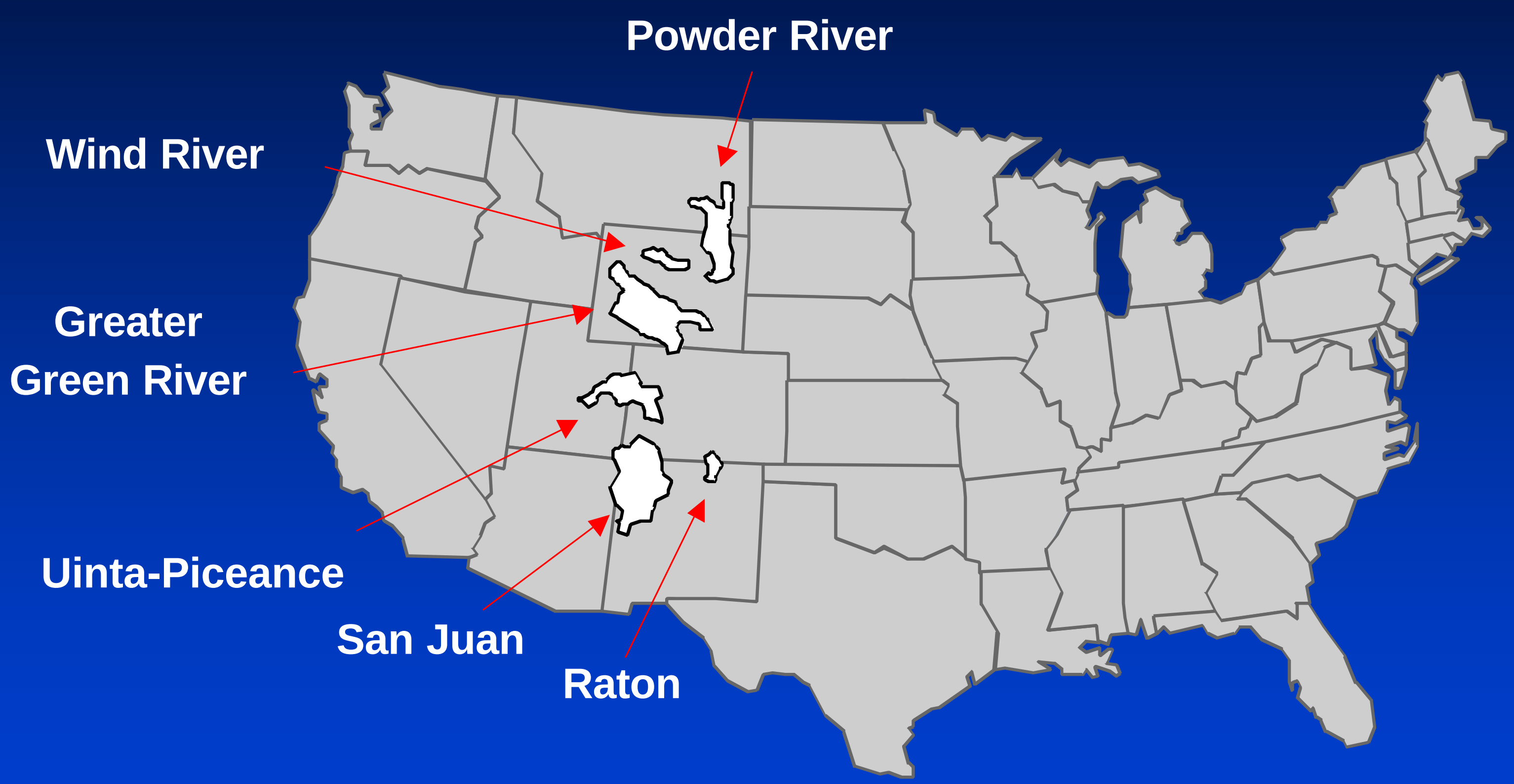
EPA Outreach Activities

- Correspondence from EPA Region 8
- Conference call with state and government regulatory officials
- Conference calls with CBM operators
- Site visits in Gillette, WY on August 6 and 7, 2001 with CBM operators
- Site visits in Gillette, WY on August 8, 2001 with CBM surface land owners and environmental groups
- Announcement of public meeting in *Federal Register*
- Public meeting on September 25, 2001
- EPA Region 8 web site

Overview of CBM Operations in Region 8

- CBM Basins in Region 8 include:
  - Powder River, Raton, San Juan, Uinta-Piceance, Greater Green River, Wind River
- Focus of analysis on Powder River & Raton Basins
  - Quality of water may allow beneficial reuse
  - Volume of produced water increases economic impacts of disposal options
  - Demonstrate range of produced water management options

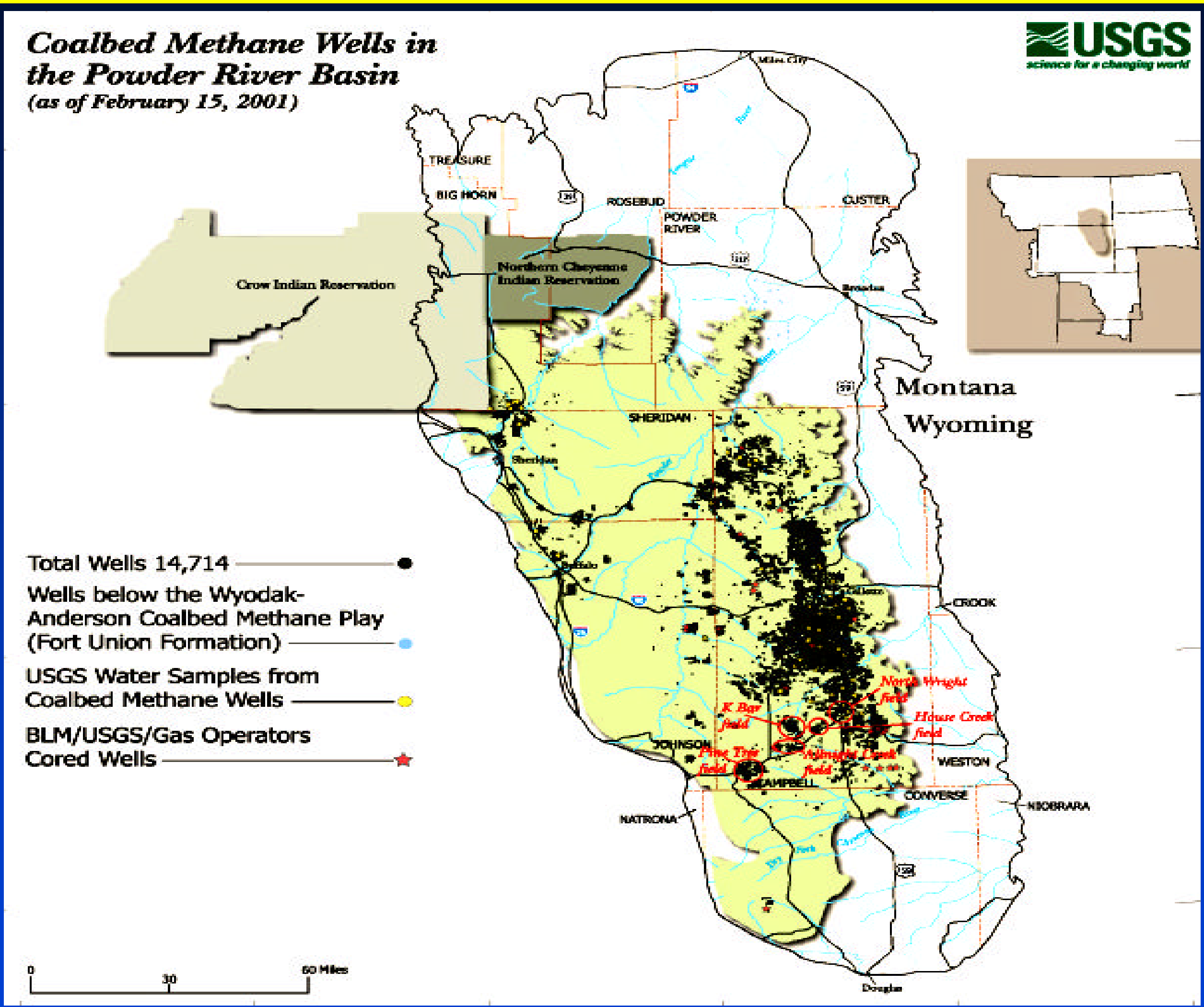
CBM Basins in EPA Region 8



CBM Production in the Powder River Basin

- Powder River Basin is 78 miles wide, 62 miles long, 8 million acres in southeast MT and northeast WY
- 126 current CBM operators
- 5,122 producing wells in 2000
- 151.5 million Mcf produced gas in 2000
- 377.9 million barrels of produced water in 2000
- Amount of water currently being discharged is a data gap

CBM Permitted Wells In the Powder River Basin



Source: USGS , A Field Conference on Impacts of Coalbed Methane Development in the Powder River Basin, Wyoming, 2001

CBM Production in the Raton Basin

- 4,000 square mile area in southeastern CO and northeastern NM
- 6 current CBM operators
- 610 producing wells in 2000
- 51 million Mcf produced gas in 2000
- 41 million barrels of produced water in 2000
- Amount of water currently being discharged is a data gap

CBM Produced Water Characteristics

- Currently water is primarily produced in the eastern part of the Powder River Basin from thick coals in the Paleocene age Fort Union Formation
  - Development is expanding to the northwest
  - Up to 10 wells drilled per day
- Powder River Basin CBM water has sodium as dominant cation and bicarbonate as the major anion
  - Constituent concentrations generally increase as well location moves from east to west and south to north
- Sparse data on organics available
- **Composition of Raton Basin CBM water is data gap**

Powder River Basin CBM Water Characteristics

Parameter	Minimum Value (mg/l)	Maximum Value (mg/l)	Mean Value (mg/l)
TDS	270	2010	862
Sodium	110	800	305
Calcium	5.9	200	36
Magnesium	1.6	46	16
SAR	5.7	32	11.7
Iron	0.02	15.4	0.8
Barium	0.1	8	0.6
Chloride	3	119	13
Sulfate	0.01	17	2.4

Source: USGS Water Co-produced with Coalbed Methane in the Powder River Basin, Wyoming: Preliminary Compositional Data, 2000

Powder River Basin CBM Water Characteristics

Parameter	Mean Value (mg/l)					
	Range 71	Range 72	Range 73	Range 74	Range 75	Range 83
TDS	540	621	780	910	1390	1580
Sodium	176	199	253	313	556	574
Calcium	30	43	41	43	22	NA
Magnesium	13	17	20	15	14	25
SAR	7.1	7.4	8.2	10.8	23.1	34.8

Sources: USGS, Water Co-produced with Coalbed Methane in the Powder River Basin, Wyoming: Preliminary Compositional Data, 2000;
BLM, Water Resources Technical Report: Montana Statewide Oil and Gas Environmental Impact Statement and Amendment of the Powder River and Billings Resource Management Plans, 2001

Overview of Potential Water-Quality Impacts

- Groundwater/drinking water contamination or drawdown
- Alteration of stream morphology and sediment generation
- Surface water and riparian zone alteration
- Local environment alteration

Groundwater/Drinking Water Contamination and Drawdown

- Groundwater/drinking water contamination and recharge
  - Surface discharge can result in infiltration of produced water contaminants to drinking water supplies or sub-irrigation supplies
- Drawdown
  - Example: Wyodak EIS modeling predicts the maximum extent of drawdown to extend up to 30 miles from the point of maximum drawdown within areas of dense development
  - Recovery of water levels occurs as production declines with the modeled maximum extent of drawdown decreased 2 to 5 miles by 30 years post-production, with a rapid recovery period within 5 years

Alteration of Stream Morphology and Sediment Generation

- Changes from intermittent flow streams to continuous flow, resulting in:
  - Erosion
  - Sediment loading
- Examples:
  - CBM produced water is usually sediment free; however, discharge to creeks can increase sediment loading from erosion
  - Accelerated soil loss due to removal of vegetation; leveling of work areas; or placing wells on slopes

Surface Water and Riparian Zone Alteration

- Quantity and quality of surface water flows
- Toxicity
  - Specific ionic composition is more of a determinant than total ion concentration; (STR) Salinity/Toxicity Relationship as tool to predict toxicity
  - Transformation of intermittent, freshwater streams to brackish continuous streams
  - Invasion of new plant species due to impacts on soils
  - Potential increase of salt-tolerant aquatic habitats (ponded water or reservoirs)

Local Environment Alteration

- Disposal of excess soluble salts:
  - Causes plants to dehydrate and die
  - Are toxic at certain concentrations
  - Causes clay to deflocculate and lowers permeability of soil to air and water
  - Inhibits root penetration
  - Hinders emergence of seedlings
  - Elevates pH which can lower availability of nutrients

Local Environment Alteration (Cont.)

- Endangered Species and Critical Habitats potentially in project area
  - 3 species listed as threatened or endangered; 3 species listed as candidate species by USFWS
  - 27 species listed by FS as sensitive species
  - Concerns:
    - Habitat disturbance (noise, human disruption)
    - Creation of barriers to movement
    - Increased human presence
    - Deaths due to poaching/vehicle collisions
  - An ESA Section 7 consultation is part of NPDES permit process

Potential Non-Water Quality Impacts

- Increased energy usage
- Increased fuel usage
- Increased air emissions
- Noise
- Dust

EPA's Data Collection Efforts

- Internet searches
- Trade associations/organizations
  - Wyoming Oil and Gas Commission - production database
  - Colorado Oil and Gas Commission - production database
  - Montana Oil and Gas Commission - production database
- Federal/state agencies
  - Bureau of Land Management publications & reports
  - WY Department of Environmental Quality permits
  - MT Department of Environmental Quality permits

EPA's Data Collection Efforts (Cont.)

- CBM operators
  - Publicly available reports
- Environmental groups
  - News stories
- Vendors
  - Price quotes
- Cost reference materials

Technology Options for Managing CBM Produced Water

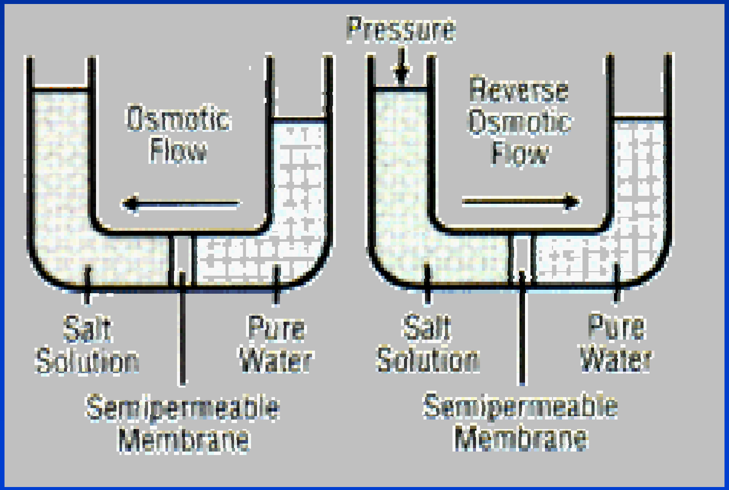
- 5 technology options included in analysis
  - Option 1: Discharge with erosion control and oxygenation to precipitate dissolved iron
  - Option 2: Option 1 + Discharge with Treatment with Criteria Limiting Key Pollutants and Discharge only to be used for Beneficial Reuse
  - Option 3: Option 1 + Discharge with Treatment with Criteria Limiting Key Pollutants and No Requirements for Beneficial Reuse
  - Option 4: Zero Discharge via Ponding
  - Option 5: Zero Discharge via Reinjection

Option 1 Description

- Surface discharge is most common practice in the Powder River Basin
  - Relatively high quality of produced water in southeastern portion of the basin
  - Large volumes of water produced
- At the permitted outfall water is typically oxygenated to precipitate out the dissolved iron to reduce/eliminate staining in the stream/creek beds
  - Rip rap used for oxygenation and erosion control

Option 2 Description

- Discharge to surface water after treatment via reverse osmosis to meet water quality standards for irrigation
- Reverse osmosis uses a semi-permeable membrane under pressure to remove aqueous salts
- Reverse osmosis is being investigated by a few CBM operators in the San Juan Basin and Powder River Basin



Option 3 Description

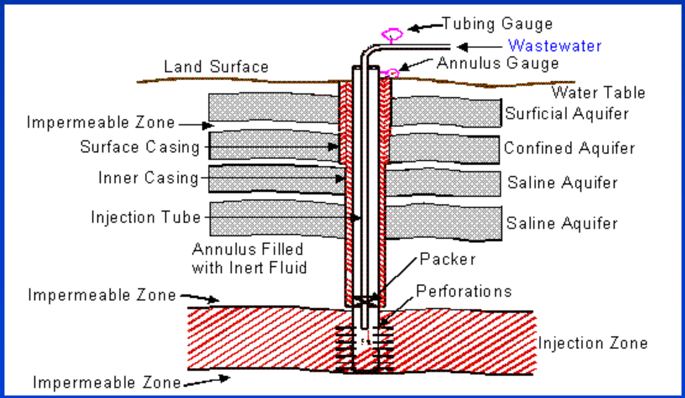
- Option 3 is identical to Option 2 in terms of technology description and costing methodology
- Under Option 3, the ultimate use of discharged CBM treated effluent is not specified. After treatment the discharged CBM treated effluent may or may not be used for irrigation or livestock watering.

Option 4 Description

- Currently, in areas where surface discharge is not viable, CBM produced water may be stored in unlined earthen infiltration and/or evaporation ponds
- High evaporation and infiltration rates in the Powder River Basin reduce the size of the ponds
- Ponds can also be used for livestock watering
- Common method of water management in the Powder River Basin

Option 5 Description

- CBM water can be reinjected into deep aquifers using Class II UIC wells for saltwater disposal
  - Reinjection into shallow aquifers via Class V wells is possible but this is not costed as an option due to the technical infeasibility of injecting 100% of the produced water into shallow aquifers in the Powder River Basin
- Reinjection of CBM produced water is the primary disposal method in the San Juan Basin



General Costing Methodology

- For each option, the costs associated with designing and implementing the technology are developed using the following steps
  - Develop technology specifications
  - Identify all capital and operating and maintenance cost components
  - Obtain unit component costs from CBM operators, vendors, or other industries if applicable
  - Calculate costs using Excel spreadsheets
  - Develop cost curves for volume of produced water
  - Insert appropriate cost per volume of produced water into the economic impact model

General Costing Methodology (Cont.)

- Cost curves will be prepared by calculating costs for aggregating water from 2, 8, 16, 24, and 32 wells for treatment
- The following cost factors will be added to capital costs as appropriate: site preparation, electrical systems, mechanical systems, instrumentation, contractor markup, startup and testing, field office expenses, insurance, overhead and profit, and contingency
- Operating costs will include maintenance, equipment replacement, labor, and energy

General Costing Assumptions

- Average lifespan of CBM well is 15 years
- Average CBM produced water production is 12 gpm
- 1/4 mile of buried flowlines per well required unless otherwise specified
- Abandoned oil and gas wells will be used as injection wells
- Gravity flow into injection wells
- Evaporation rate is 48 inches/yr
- Infiltration rate is 48 inches/yr
- Land acquisition costs are $400/acre

Option 1: Surface Discharge Costing Methodology

- Unit component costs include:
  - Discharging via buried water flowlines
    - 2001 RSMeans Building Construction Cost Data
  - Rip rap
    - Limestone rocks
    - Depth of 1 foot
    - 2001 RSMeans Site Work and Landscape Cost Data
  - Land acquisition for buried flowlines

Options 2 & 3: Discharge after Treatment Costing Methodology

- Unit component costs include:
  - Equipment building
    - 2001 RSMeans Building Construction Cost Data
    - Vendor costs
  - Influent and effluent holding tanks
    - 20,000 gallon tanks
    - Vendor costs
  - Reverse Osmosis system designed to remove TDS and salts
    - At least 95% effective in TDS and salt removal
    - Vendor costs

Options 2 & 3: Discharge after Treatment Costing Methodology (Cont.)

- Pump
  - Vendor costs
- Discharge of treated water via buried flow lines to permitted outfall
  - 2001 RSMeans Building Construction Cost Data
- Discharge of effluent via underground injection wells
  - Buried flowlines to existing injection well
    - 2001 RSMeans Building Construction Cost Data
  - Well workover
    - Previous Oil & Gas ELG costs
- Land acquisition for treatment area and buried flow lines

Option 4: Zero Discharge via Ponding Costing Methodology

- Earthen storage ponds are excavated and designed off-channel to hold water from a 25-year, 24-hour storm event and CBM water at a fixed depth
- Unit component costs include:
  - Excavation
    - 2001 RSMeans Site Work and Landscape Cost Data
  - Buried flowlines
    - 2001 RSMeans Building Construction Cost Data
  - Pea gravel to improve infiltration
    - 2001 RSMeans Site Work and Landscape Cost Data
  - Land acquisition for pond and buried flowlines

Option 5: Zero Discharge via Reinjection Costing Methodology

- Assume operations can use an abandoned conventional oil and gas well for reinjection after well makeover
  - No pretreatment required
  - Well located within piping distance; transportation not required
- Unit component costs include:
  - Well makeover
    - Previous Oil & Gas ELG costs
  - Buried flowlines
    - 2001 RSMeans Building Construction Cost Data
  - Land acquisition for buried flowlines

Non-Water Quality Impacts (NWQI)

- The NWQI analysis considers the impacts of CBM produced water treatment/disposal in terms of increased energy demand from the use of equipment required under each of the technology options proposed by EPA
- This increase in energy demand results in an increase in fuel usage, air emissions, and noise that can be quantified over the life of each CBM well

NWQIs By Technology Option

- Option 1: Surface Discharge
  - No incremental NWQIs
- Option 2: Discharge with Treatment for Beneficial Reuse as Irrigation Water
  - Increased fuel usage and air emissions result from equipment needed for reverse osmosis treatment
    - Pumps
    - Effluent and backwash water disposal
      - Gravity fed to reinjection well and no NWQIs

NWQIs By Technology Option (Cont.)

- Option 3: Discharge with Treatment with Criteria Limiting Key Pollutants
  - Same as Option 2
- Option 4: Zero Discharge via Ponding
  - Fuel usage and air emissions result from excavation equipment needed for construction of ponds
- Option 5: Zero Discharge via Reinjection
  - Assuming gravity flow into existing injection wells, therefore, no incremental NWQIs

Modeling Approach to Measure Economic Impacts

- Discounted cash flow models of individual projects are being developed
- 36 model projects will be used to represent the range of CBM operations in EPA Region 8
- Models will measure the effects of regulatory costs on production, project life, net present value of project, royalties collected, and state and federal taxes collected

Economic Model Characteristics

- Characteristics of the model projects are based on information from:
  - Existing projects in the Powder River Basin in Wyoming and Montana
  - Existing projects in the Raton Basin in Colorado
  - Information from operators
  - Assumptions where no data are provided

Economic Model Characteristics (Cont.)

- Key characteristics include:
  - Gas and water production volumes
  - Operating costs
  - Construction costs
  - Wellhead price of gas
  - Royalty rate
  - Severance tax rate
  - State and federal corporate tax rates

Economic Model Characteristics (Cont.)

- Models developed for:
  - Different gas production level scenarios - high, medium, low
  - Different gas/water efficiency scenarios - high, medium, low
  - 3 Regions - East, Central, West (including Montana)
  - Existing projects
  - Transitional projects (too young to model maximum gas production)
  - New projects (future)

Economic Model Characteristics (Cont.)

- Each of the 36 models represent:
  - An assigned number of existing and transitional projects
  - An estimated number of future projects

How Does The Analysis Work?

- For each year of operation, net revenues are compared to operating costs
- This comparison is made for 30 years of operation, or until operating costs exceed revenues, at which time the project is assumed to shut in
- Then, for the estimated lifetime of the project, total production and total net present value are calculated

How Does The Analysis Work? (Cont.)

- Net revenues are calculated based on:
  - Wellhead prices
  - Production volumes
  - Royalties and severance taxes

How Does The Analysis Work? (Cont.)

- Total costs include:
  - Costs that affect the shut in decision:
    - Production costs
    - Produced water use or disposal costs
  - Costs that do not affect the shut in decision but affect the bottom line:
    - Capital expenditures
    - Income taxes

How Does The Analysis Work? (Cont.)

- Net present value (NPV) of individual projects measures the value, in today's dollars, of the net annual income over the life of the project
  - If NPV is positive, then the project is a good investment (i.e., it is greater than the discount rate or opportunity cost of capital)
  - If NPV is negative, then the project is not a good investment, and money could have been better invested elsewhere

Assessing Regulatory Impacts

- Each model is run twice - once without additional costs of produced water management options (baseline) and once with those costs
- Total NPV at the baseline and with each management option are compared
- If total NPV goes from positive in the baseline to negative after management option costs are incurred, the project is assumed to shut in immediately and production losses are calculated

Assessing Regulatory Impacts (Cont.)

- For projects that do not shut in immediately, baseline values for production, net present value, taxes, and royalties are compared to the values estimated assuming additional produced water management costs are incurred and the differences are calculated as impacts on that project
- Impacts associated with all model projects are aggregated

Overview of Model Operations in Each Region

Region	Number of Projects			Number of Producing Wells per Project in 2000	Range of Model Project Gas Production (Mcf/yr)	Range of Model Project Water Produced (bbls/yr)	Range of Water to Gas Ratios (bbls/Mcf)
	Existing	Transitional	New				
East	269	131	500	2 – 9	2,754 – 478,389	4,712 – 1,584,351	0.2 – 170.5
Central	169	172	500	2 – 10	575 – 706,657	58,688 – 1,139,568	0.6 – 255.0
West	56	81	3,000	3 – 25	5,542 – 652,864	102,064 – 4,885,501	1.5 – 93.2

Production Related Assumptions

Parameter	Value or Values	Source
Number of wells drilled to date	Varies by model project	WY and MT production databases
Project timing (number of years between leasing and exploratory drilling, between exploration and delineation and development, and between development and operation)	Leasing to development to operation is assumed to occur in Year 1 No true exploration and delineation phase assumed	CBM operators
Rate of installation of any new wells on existing projects	Additional wells (potential wells) assumed to be installed in Year 1 No drilling costs assumed to have incurred to date	CBM operators
Peak production rate	Varies by model project	WY and MT production databases
Current existing production	Varies by model project	WY and MT production databases
Production decline rates	From maximum gas production (assumed to occur in Year 2 of new and transitional projects) or from current gas production in existing projects, 13% per year From maximum water production (assumed to occur in Year 1 for all projects), 30% per year	WY production database
Initial produced water production	Varies by project	WY and MT production databases

Cost Related Assumptions

Parameter	Value or Values	Source
Lease cost	$400/acre	Coal Bed Operators Information Survey Report
Total lease cost per project	$256,000	Assumption based on geographic area of 1 project (1 square mile) and lease cost per acre as above
Geophysical and Geological Costs	Assumed $0	EPA assumption
Drilling costs	$60,000 - $150,000 depending on location $500,000 Raton Basin	Coal Bed Operators Information Survey Report
Additional infrastructure cost (pod buildings, piping, etc.)	$22,000	Coal Bed Operators Information Survey Report
Operation & maintenance costs (excluding variable costs of produced water treatment & discharge)	$0.26/MMcf	Coal Bed Operators Information Survey Report
O&M costs for produced water (per bbl)	Baseline = $0; post-compliance to be calculated by EPA	Baseline set equal to 0 for simplicity
Capitalized costs	Intangible drilling costs are expensed, IDCs represent 60% of the cost of production wells and their infrastructure, integrated producers can expense 70% of IDCs (42% of well drilling costs) and independents can expense 100% (60% of well drilling costs) with the remainder capitalized and treated as depreciable assets	IRS rules

Other Economic Assumptions

Parameter	Value or Values	Source
Marginal corporate tax rates	34% Federal, 6.6% average state corporate tax	IRS maximum rate; State Tax Handbook
Severance taxes	0.06% of sales (WY) ~15% of taxable value of production (MT) All rates are for established wells WY rate will be used for all models except West3 group which will run MT rates for existing projects West3 new and transitional projects will be run under WY or MT rates	Form OG-0001 on the WOGCC website; report on current and proposed changes to tax rates in MT MT rates may be lower in future
Royalty rate	16%	Midpoint of range in Coal Bed Operators Information Survey Report
Depreciation	Modified Accelerated Cost Recovery System will be used	Previous Oil and Gas economic impact analyses
Basis for depreciation	100% of total capitalized costs	IRS rules
Inflation rate	3%	Previous Oil and Gas economic impact analyses
Depletion Allowance	For independents, 15% on up to 1,000 barrels of oil equivalent For majors use cost basis depletion	IRS rules
Real discount rate	7%	Office of Management and Budget
Wellhead price of oil and gas	$3.00/Mcf,with sensitivity analysis on lower and higher prices (assumed net of transportation costs)	CBM operators

Additional Data Needs

- Industry profile data
  - Water characteristics for Raton Basin
  - Water characteristics for western portion of Powder River Basin
  - Volume of produced water by current use or disposal method in Powder River Basin and Raton Basin
  - Financial assumptions specific to Montana and/or Raton Basin, if different from those presented
- Technology cost data
  - Reinjection unit component costs and flows
  - Pond designs and unit component costs

Schedule for Completion of Analysis

- Cut-off date for any input data for Draft BPJ report is October 11, 2001.
- Draft BPJ report in November 2001
  - Announcement of availability will be made in Federal Register and through stakeholder contact list
  - Posted on EPA Region 8 website
  - 30-day review period
- Public meeting to discuss draft report will be held during the public review period
- Final BPJ report in January 2002

For More Information Contact…

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http://www.epa.gov/region08/water/wastewater/npdeshome/cbm/cbm.html